30.72
1966
138

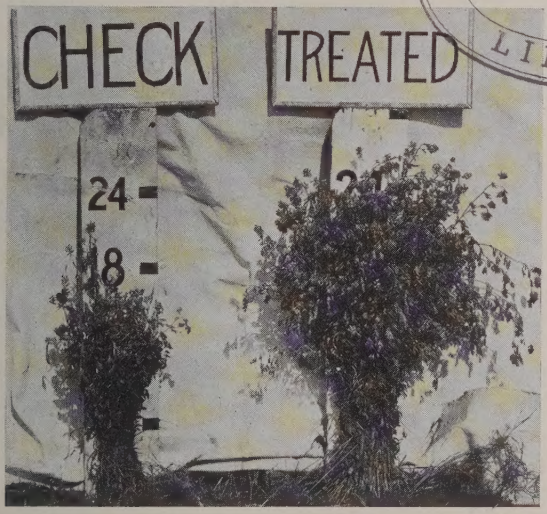
MOSCOW, SEPTEMBER 1941 EXTENSION BULLETIN NO. 138

UNIVERSITY OF IDAHO
COLLEGE OF AGRICULTURE
Extension Division
E. J. IDDINGS
Director

Fertilizers for Idaho Farms

By H. W. E. Larson

UNIVERSITY OF ARIZONA
MAY 9 1942
LIBRARY



COOPERATIVE EXTENSION SERVICE IN AGRICULTURE AND HOME ECONOMICS
OF THE STATE OF IDAHO, UNIVERSITY OF IDAHO COLLEGE OF
AGRICULTURE, AND UNITED STATES DEPARTMENT
OF AGRICULTURE, COOPERATING

SOILS SECTION

Printed and Distributed in Furtherance of the Purposes of the Co-operative Agricultural Extension Service Provided for in Act of Congress, May 8, 1914.

Table of Contents

Summary 3
Introduction 5
Soil Testing and Field Testing for Plant Food Requirements 7
General Information Regarding Various Plant Food Elements 8
- Primary Plant Food Elements 8
  - Nitrogen 8
  - Phosphorus 10
  - Potassium 11
  - Sulphur 11
- Secondary Plant Food Elements 12
  - Iron 12
  - Boron 13
  - Magnesium 13
  - Manganese 14
- Soil Amendment 14

Crop Fertilizer Recommendations 15
- Forage Legumes 17
- Beans 18
- Beets 18
- Corn 19
- Fruit Trees 19
- Grains 19
- Onions 20
- Pastures 20
- Peas 21
- Potatoes 21
- Truck Crops 22

Methods of Application of Commercial Fertilizers 22
- Gypsum and Calcium Cyanamid 23
- Potash 23
- Manure 23
- Phosphates 23
- Boron 23
- Magnesium 23
- Iron 24
- Manganese 24
- Limestone 24

Home Mixing of Fertilizers 24
Residual Effect 28
Appendix 30

SUMMARY

Fertilizer trials have shown: (1) that soils in many parts of Idaho have become depleted in available plant food, and (2) that crops growing thereon are responding very profitably to the application of adapted fertilizers, including farm manures and green manures.

The use of commercial fertilizer should be considered as supplemental to the practice of a good rotation, the incorporation in the soil of large quantities of organic matter in the form of farm manure, crop residues and green manures, and the maintenance of good soil tilth.

Each of the plant foods discussed in this bulletin performs a specific function in the plant. The functions of nitrogen, phosphate, potash, sulphur, iron, boron, magnesium, and manganese are discussed. The effect on the plant of insufficient plant food as well as the presence of excessive amounts in the soil also is discussed. Information regarding the functions of plant foods not discussed in this bulletin can be obtained by writing to the Extension Soils Specialist, University of Idaho, College of Agriculture, Moscow, Idaho.

The need for fertilizer applications may be determined by studying the plant symptoms, analyzing the soil for available nutrients, conducting soil plat tests, or by treating small strips in the field with various fertilizers. Results obtained by harvesting small, differently treated strips in the field are the best basis upon which to base a future fertilizer program.

The value of farm manure applications to the soils in Idaho, with the exception of areas where moisture is the limiting factor, has long been recognized. However, small applications in areas of low rainfall also have proved profitable when considered on a long-time basis.

The application of soluble phosphate fertilizers has been found profitable on the majority of the soils in the Snake River plain area. The response has not been uniform in the southwestern Idaho area. Response from phosphate has been obtained on peat and muck soils, and certain mineral soils in northern Idaho.

The application of nitrogenous fertilizers is frequently profitable where insufficient farm manures and green manure crops are available. The application of small amounts of nitrogen together with phosphate has been found profitable wherever the soils low in active organic matter respond to phosphate applications.

The starting of new stands of forage legumes in northern cut-over areas may be facilitated by the application of small amounts of nitrogenous fertilizers.

The application of potash fertilizers has proved profitable on certain truck crops. Only in a few areas has its use been found profitable on forage legumes. Peat and muck soils respond to high potash-containing complete fertilizers. Potash fertilizers are usually applied in combination with phosphate or in complete fertilizers.

Forage legumes in northern Idaho respond to the application of sulphur-containing fertilizers such as gypsum. Marked response from gypsum applications to forage legumes also has been obtained in some of the mountain valleys lying in Adams, Valley, Payette and Gem counties, and the northern part of Washington county. Alfalfa grown on some cut-over soils has responded to very light applications of borax.

Commercial fertilizers are usually applied on the land every two to four years when in legumes, and every year when in row crops. Main crops which usually receive applications are truck crops, potatoes, beets, forage legumes and grain. The other crops in the rotation may use the fertilizer residue.

Rates of fertilizer application vary widely. Gypsum is usually applied at the rate of 200 pounds per acre every other year. Soluble phosphate is applied at the rate of 50 to 200 pounds per acre on beet ground; and at the rate of 100 to 300 pounds to other crop land. The higher rates of application have proved most profitable, especially when the land is receiving its first application. Ammonium sulphate is applied at varying rates, about 30 pounds on dryland stubble up to 200 pounds on row crops in the irrigated areas. Potassium sulphate is applied at rates varying from 100 to 250 pounds per acre in combination with phosphates.

Fertilizers are broadcast on forage legumes and grain crops. Applications to row crops should be made by means of fertilizer attachments. However, profitable response over a longer period also can be obtained by broadcasting larger applications than are necessary when applying with fertilizer attachment equipment on planters and cultivation machinery.

Where complete fertilizers are necessary, it may prove profitable for the farmer to do his own mixing. The spread in price between the retail cost of the ingredients and the retail price of the fertilizer formula should be considered before doing any mixing.

Fertilizers for Idaho Farms

H. W. E. LARSON[1]

Introduction

SOIL fertility has decreased in many areas in Idaho during the past 15 to 20 years. This has been due to the prevailing crop system, non-utilization of crop residues and farm manures, erosion, and exhaustion of the available supply of plant food in the soil. For example, alfalfa and beet yields have decreased considerably in many localities. Idaho has long been famed for high quality red clover seed. The seed yield of this valuable legume also has decreased in many localities. Experiments and demonstrations have shown that the former seed yield of this legume can be restored and in some instances increased by the use of phosphate fertilizers. These demonstrations also show that under prevailing cropping systems there is a deficiency of one or several plant food elements which are necessary for the production of high yields of crops in certain localities and on many soil series.

Due to our favorable climate, high-yielding crops remove available plant foods from the soil faster than they are made available or the supply replenished by the activity of bacteria in the soil and by the application of farm manures available on the farm. Numerous demonstrations on farms in various localities of the State where insufficient manure is available have shown that, in order to obtain economical crop production, some form of commercial fertilizer should be used to supplement farm manure. The use of commercial fertilizers always should be considered as supplemental to the practice of a good rotation, the incorporation of large quantities of organic matter in the form of farm manure, crop residues, green manures, and the maintenance of good soil tilth.

The absence of a soil-conserving rotation and the nonreturn of sufficient farm manures and field crop residues to the land have further hastened the depletion of the fertility. The practice of rotation permits the soil to renew to some extent the supply of available plant food from the non-available supply. Some of the unavailable plant food is changed to an available form by the action of products of decomposition of farm manure and green manure crops. The amounts of the three most important plant foods hauled off the farm in forms of various crops are presented in Table I. For example, a 50-bushel crop of wheat (3,000 pounds) removes 60 pounds of nitrogen, 25.8 pounds of phosphoric acid, and 12 pounds of potash from the soil. The difference in the amounts of plant food removed from the farm when crops are sold directly as compared with marketing through livestock fed on the farm can be calculated from the data presented in this table. It is more difficult to maintain a high state of soil fertility when all forage and grain products are sold directly from the farm in place of

[1] Extension Soils Specialist.

disposing of them through animal products. This latter system of farming permits the return of large quantities of plant food to the land in the form of farm manure.

The yields of crops can be maintained and increased in many instances under both livestock and non-livestock systems of farming by the utilization of crop residues and green manure crops, both legume and nonlegume, and the judicious use of commercial fertilizers.

Table 1.—Chemical analyses of plants and animals per 1000 pounds[2]

Crop	Nitrogen lb.	Phosphoric Acid—lb.	Potash lb.
Alfalfa hay	23.80	5.40	22.30
Red clover hay	21.00	5.00	20.00
Red clover seed	30.00	15.00	14.00
White sweet clover	23.20	6.60	12.60
Bean straw	11.70	4.20	13.60
Kentucky blue grass	6.60	1.90	7.10
Wheat grain	19.80	8.60	5.30
Oat grain	19.80	8.10	5.60
Barley grain	18.40	8.50	7.40
Corn grain	15.90	6.80	3.90
Potato tubers	3.50	1.20	5.30
Sugar beets	2.60	0.80	3.20
Whole milk	5.60	2.00	1.70
Fat steer—(weighing 1200 pounds)	25.60	18.39	2.05
Fat sheep	20.80	10.40	1.48
Fat hog	12.40	6.54	1.38
Asparagus	3.50	1.00	2.50
Beans	2.50	0.80	3.00
Cabbage	3.00	1.00	4.00
Cauliflower	2.80	1.00	3.33
Celery	2.50	2.00	7.50
Sweet corn	4.50	2.00	3.00
Lettuce	2.50	0.80	4.50
Onions[3]	2.30	0.90	2.20
Muskmelon	2.20	0.80	4.00
Peas	11.50	3.00	4.50
Spinach	5.00	1.50	2.50
Tomatoes[3]	2.00	0.70	3.50
Watermelons	1.70	0.60	3.00

[2] Henry, W. A., and Morrison, F. B., *Feeds and Feeding*, Ed. 2, 770 P, Illus. Madison, Wis., 1923.
[3] Van Slyke, Lucius, *Fertilizers and Crop Production*, p. 493, Illus. New York, 1937.

Plants require relatively large quantities of carbon, hydrogen, oxygen, phosphorus, potassium, nitrogen, sulphur, calcium, and magnesium for optimum development. Relatively small amounts of secondary elements such as iron, manganese, zinc, boron, copper, and others also are necessary for growth. Very little is known at present regarding the value of these minor elements under Idaho conditions. Carbon and oxygen are obtained from the air as gases, while the other nutrient elements are obtained from the soil solution. However, supplies of nitrogen are obtained by legume plants from the soil air by means of bacteria in the nodules, and the plants in turn supply energy-containing foods to the bacteria.

A large proportion of the nitrogen can be supplied by the growing and the plowing under of top growth of green legume crops and by the proper utilization of barnyard manure. Only four or five of these plant foods are apt to be limiting factors in plant development, under most conditions. In Idaho these are phosphorus, sulphur, nitrogen, potash, and iron in high lime soils. The above-mentioned mineral elements and others are present in the soil in readily available (soluble), very slowly available, and non-available forms. Plants can use only the readily available form.

Contrary to the belief of many people, it is not necessary to continue every year the application of commercial fertilizers, with the possible exceptions of readily soluble nitrogenous fertilizers to special crops. However, many farmers find it profitable to apply them every year for a few years and then continue their use intermittently, probably applying them only to the legume crop or to some other crop in the rotation. The profitableness of this continued use is due to the harvesting of larger crops than otherwise would be possible.

Commercial fertilizers should be purchased on the basis of plant food content and price, but not price alone. The price of fertilizers should be compared on their unit of plant-food-content cost-basis. The cost per pound of plant food element such as nitrogen, phosphorus, and potash varies depending upon demand, cost of manufacture, content in fertilizer, and economic conditions. (During war time, nitrogen and potash usually cost more per unit than during peace time.) A unit is 20 pounds of available plant food per ton, or 1 per cent of a ton. High analysis fertilizers usually cost less per unit of plant food than do low analysis products, because of the lower freight, storage, handling, and filler[4] cost. For example, it is more economical to pay $50 for a 6-30-0 fertilizer than to pay $36 for a 3-13-0 fertilizer[5].

The reasons for discussing the use of commercial fertilizers in this bulletin are their specific value in promotion of plant growth and the current wide demand for knowledge regarding their usage. Some of the questions which farmers are asking are: "How can I determine that I have a fertilizer problem? Which fertilizer element or elements are lacking? What are the plant symptoms of various fertilizer deficiencies? How much should be applied? When and how should they be applied? Frequency of application? Can various fertilizers be mixed economically?" This bulletin is presented as a source of information in answer to the above and many other questions which arise every day on the farm.

Soil Testing and Field Testing for Plant Food Requirements

There are various ways of determining whether a soil is deficient in certain plant foods. Common methods are analysis of the plant tissue; chemical soil analysis for available plant food; studying the symptoms of deficiency in the plant (discussed under each plant nutrient); growing of plants in pots containing small quantities of

[4] See meaning of "Filler" under definition of terms in the appendix.
[5] See meaning of "Complete Fertilizer" in the appendix.

soil, each of which has received a different treatment; and conducting field trials in which each plat is treated differently. This latter method gives the most practical information.

Indications of certain plant food deficiencies can be determined by means of soil analysis for available plant food. In most instances, however, the results of any soil analysis should be considered only as indicative of the deficiency condition in the soil, and field trials should then be conducted in which the deficient element is applied to verify the findings. (See indications of deficiency in the plant under "General Information Regarding Various Plant Food Elements.")

In carrying on field trials only small plats need be treated. One-twentieth acre plats (20′ x 109′) are sufficiently large in forage, or grain fields, and 6- to 16-row-wide plats in row-crop fields.

Since there is considerable border effect next to fences, the first no-treatment area should be of double width. There should also be a check (no-treatment) bordering every treatment. Sometimes it may be advisable to repeat the series of treatments because of lack of soil uniformity. Whenever the fertilizer material is applied broadcast to row crops, it should be done before the final disking and harrowing and at a heavier rate than when applying it by means of fertilizer attachments on planters or drills. Several plats can be treated in accordance with the following plan:

Fence 10-ft. Guard area	Check (No treatment)	Treatment 1	Treatment 2	Check (No treatment)	Treatment 3

The profitableness of any treatment can be determined by harvesting and weighing the yield on each plat; or only harvesting the forage from 6 areas 3 feet square (9 square feet) in hay demonstrations, harvesting 6 areas consisting of 2 rows 1 rod long in grain crop plats or 1 or 2 middle rows in row-crop plats. Only by actually harvesting known areas can accurate information regarding the profitableness of the treatment be obtained.

General Information Regarding Various Plant Food Elements.

Primary Plant Food Elements

The various plant food elements perform specific functions in the plant. The available supply of nitrogen, phosphate, and potash usually becomes deficient much sooner than that of the other necessary plant foods due to the heavy plant requirements of these three.

Nitrogen. The soil nitrogen reserve supply is present in the humus. Humus is partially decomposed organic matter which

furnishes food for helpful bacteria. The desert and cut-over soils are naturally low in nitrogen.

The functions of nitrogen are (1) to produce rapid foliage growth, (2) to impart green color to plant, and (3) to stimulate early growth. However, when nitrogen is present in excessive amounts, it may lower plant resistance to disease, delay flowering and maturity, and cause "burning" in cereals.

Deficiency symptoms are poor leaf development and poor coloring (yellowing).

The sources of nitrogen are farm manure, plowed under top growth of forage legumes, ammonium sulphate, sodium nitrate, cyanamid, and other commercial nitrogen carriers. A ton of average farm manure contains 10 pounds of nitrogen, 5 pounds of phosphoric acid, and 10 pounds of potash. A portion of the nitrogen in farm manure is quickly available to the plant, and all of it is rendered available over a period of a few years. The cost of nitrogen in commercial fertilizer is at least 12 cents per pound.

Nitrogen present in ammonium sulphate and sodium nitrate is quickly available. Because of its slightly acid forming ability, ammonium sulphate should be used on southern Idaho soils where there is an excess of lime present. The continued application of large amounts of sodium nitrate may have a detrimental effect

Table 2.—Composition of the principal fertilizer material[6]

Fertilizer materials	Nitrogen	Phosphoric acid		Potash (water soluble)
		Available	Total	
	Per cent	Per cent	Per cent	Per cent
Nitrogenous fertilizers				
Nitrate of soda	16	.....	.....	.....
Sulphate of ammonia	20-21	.....	.....	.....
Cyanamid	21-22	.....	.....	.....
Nitro-phosphatic fertilizers				
Tankage	6-8	5-6	7-12	.....
Fish scrap, fish meal	7-10	.....	3-6	.....
Bone meal or flour	2	10	18	.....
Ammo-phos. "A"	11	48	.....	.....
Ammo-phos. "B"	16	20	.....	.....
Ammonium phosphate	10	52	.....	.....
Phosphate fertilizers				
Superphosphate	.....	16-20	18-22	.....
Treble or double superphos.	.....	35-45	.....	.....
Ground rock phosphate	.....	2-5	25-35	.....
Potassic fertilizers				
Muriate of potash	.....	.....	.....	48-60
Sulphate of potash	.....	.....	.....	48-50
Wood ashes (unleached)	.....	.....	1.5-2.5	4-6

[6] Information regarding any fertilizer not mentioned in this list can be obtained by writing to the Extension Soils Specialist, University of Idaho, Moscow, Idaho.

on the physical conditions of alkaline soils low in lime. Fishmeal (7 per cent nitrogen) is an organic fertilizer used when a source of slowly available nitrogen is desired. It is most frequently used in mixtures prepared for use on truck farms. The cost per pound of nitrogen is quite high. Cyanamid (21 to 22 per cent nitrogen) should be used only on acid soils because of its high lime content,

and it also can be used advantageously in decomposing crop residue and trashy farm manures for greenhouse and truck crop uses. Since it will cause burning of seedlings if applied at seeding time, it should be applied about two weeks previously.

Nitrogen-containing fertilizers are of value on run-down soils where nonlegume plants are grown. They also stimulate the growth of new legume seedings in the cut-over areas. When mixed with phosphates, they are of distinct benefit where phosphate applications are needed on soils low in organic matter. Available nitrogen is easily leached out of the soil, and, therefore, it is necessary to make yearly or bi-yearly applications. (See also "Crop Recommendations" and "Methods of Application.")

Phosphorus. The use of phosphate in Idaho is largely confined to the southern irrigated districts and to the drained high lime soils in the Bonners Ferry district. Some response also has been obtained on grain crops in the cut-over and southeastern Idaho wheat growing areas. The soils of southern Idaho, as a rule, are high in total phosphorus but very low in available phosphorus, which is the form plants use. In experimental work so far conducted throughout southern Idaho, no consistent increased yields have been obtained from the application of ordinary or finely ground raw rock phosphate. Rates of application have been as much as 2,500 pounds per acre. Most southern Idaho soils are high in lime or calcium carbonate. Lime is dissolved in the soil moisture due to the presence of carbon dioxide derived from decomposing organic matter and plant growth. Rock phosphate also is slightly soluble in water-containing carbon dioxide. The soluble lime reacts with the small amount of soluble phosphate to form the insoluble phosphate once more. Since it is not economical to remove the calcium carbonate, it has been found more economical to apply soluble phosphate for plant nourishment. Figure 1 shows variation in growth produced by two phosphate products.

The functions of phosphorus are (1) to stimulate early root growth and tillering, (2) to hasten maturity of nonlegumes (but it may delay maturity of legumes) (3) to increase fruit production, and (4) to stimulate leaf production of legumes.

Symptoms of deficiency are poor germination, lack of green coloring, stunted root growth, production of weak spindly alfalfa having a few small leaves (no reduction of stand).

Most of the double phosphate fertilizers sold in Idaho contain 43 per cent or more available phosphoric acid (P_2O_5). Analyses of phosphate products are presented in Table 2. Over 95 per cent of the phosphate in superphosphate, double, and treble phosphate, is present in an available form, while less than 10 per cent of the phosphorus in rock phosphate is present in an available form. Phosphate fertilizers are applied either alone or in combination with other plant food elements. (See "Crop Recommendations" and "Methods of Application.")

Superphosphate (ordinary or double strength) is not acid forming. It has no detrimental effect on the physical condition of

the soil. Phosphates are not lost out of the soil by leaching, except in very sandy soils. Phosphates, when spread on the surface, move downward slowly (2 or 3 inches during 4 or 5 years except in very sandy soils). Available phosphate present in commercial fertilizers

Figure 1.—Some differences in alfalfa yields obtained in Twin Falls county.

costs at this time 5½ to 6 cents per pound. Discussion of methods and frequency of application and residual effects is presented under "Crop Recommendations" and "Methods of Application."

Potassium. Idaho soils contain relatively large supplies of available potassium or potash. Its use has been profitable only for certain crops and under local conditions in some areas. It is to be expected that its use will increase, since relatively large amounts are hauled off from the farm each year in the form of cash crops.

The functions of potassium are (1) to facilitate production and transference of starch, (2) production of sugar in fruits and vegetables, (3) formation of fibrous matter in plants, and (4) production of fleshy and plump small fruits. On the other hand potassium delays seed maturity and fruit production.

Effects of deficiency are weak straw, small vegetative organs, yellowing of leaf, dull white to brown roots, shriveled grain. The margins of legume leaves growing on potash deficient soils first become dotted by many pale yellow to white areas, and later the margins turn brown and die. Small fruits lack plumpness and sweetness.

All potassium compounds such as potassium sulphate and potassium chloride commonly used as fertilizers are soluble in water. Very little is lost in the drainage water because it reacts with the clay in the soil. The plant can obtain its potash from this potash-clay compound. The potassium contents of various fertilizer materials are shown in Table 2.

Potash present in commercial fertilizers costs approximately 5 cents per pound. Sandy soils usually respond to potash applications although very little response has been obtained on most of the sandy soils in Idaho. Truck crops, especially the leafy ones, respond to potash applications. Potatoes and clover seed have responded to potash application in a few areas only. (See also "Crop Fertilizer Recommendations" and "Methods of Application.")

Sulphur. Sulphur is necessary for the formation of some proteins and for the production of certain odorous oils contained in

mustard, horseradish, turnips, cabbages, onions, garlic, and leeks. Most of the sulphur is present in the leaves and stems of plants. Legumes respond to sulphur applications while grain crops respond only when the soils are extremely deficient.

Sulphur-containing fertilizers consist of gypsum, flowers of sulphur, potassium sulphate, and ammonium sulphate. Gypsum (18 per cent sulphur) is the most practical and economical source of sulphur under Idaho conditions. It should be applied every two years to legume crops at the rate of 200 pounds per acre. The application of flowers of sulphur or ammonium sulphate will increase the acidity of a soil while the application of gypsum has no effect on soil reaction. All forms of applied sulphur are easily leached out of the soil. Legumes growing in northern Idaho and in the mountain valleys on the south side of the Sawtooth range respond to sulphur applications. Figure 2 shows the increased growth which can be expected from the applications of gypsum to northern Idaho cut-over soils. (See also "Crop Fertilizer Recommendations" and "Methods of Application.")

Figure 2.—Forage Legumes respond markedly to the application of gypsum in Bonner county.

Secondary Plant Food Elements Necessary for Plant Growth.

Many plant food elements which perform very important functions in the plant are occasionally deficient in soils. Plant growth is very adversely affected when the necessary supply is lacking. Iron, boron, magnesium, manganese, and zinc are some of the secondary plant food elements which, in available form, are lacking or may become so in Idaho soils.

Iron. The soils of southern Idaho, due to their high limestone content, are frequently found to be lacking in available iron.

Iron is necessary for the production of chlorophyll, the green coloring matter in plants. In the absence of chlorophyll, the plant is unable to utilize sunlight. The leaves turn yellow first between the veins and later turn white, curl, shrink, and die in the absence of sufficient available iron in the soil. This type of yellowing of the leaves is called iron chlorosis. Where the available nitrogen supply is high and the iron supply is low, a shoot frequently grows

so rapidly that iron compounds do not reach the growing tips in time to prevent the formation of yellow leaves. Soluble iron may be supplied to the plant as copperas (ferrous sulphate), iron tartrate, or iron citrate. (See also "Methods of Application.")

Boron. Very little definite information regarding the need of boron applications on Idaho soils has been obtained up to the present time. Preliminary results obtained in northern Idaho on alfalfa indicate beneficial response may be expected from small applications of boron in certain areas.

Plants require very small amounts of boron for their growth and development. Functions of boron are (1) to promote growth of leaf and the growing points of plants, (2) to strengthen the cell wall, (3) to stimulate production of flower and fruit, and (4) to stimulate movement of carbohydrates from one place to another within the plant.

Deficiency symptoms are "dying back" of the tips of the growing shoots and roots, stimulation of the production of many lateral buds which are usually misshaped, rust brown areas on cauliflower heads which become bitter and unpleasant to the taste, cracked stem and heart rot of celery, black roots of strawberry plants, and black heart disease of sugar beets. This deficiency sometimes occurs in soils receiving large applications of calcium-containing fertilizers such as gypsum.

Leaves of plants receiving an excess of boron first become yellow around the margin. The yellowing progresses toward the mid-vein or leaf base. The yellowing changes to browning of foliage in later stages.

The boron requirement of plants varies considerably depending upon the type of plant grown. The root crops such as sugar beets and turnips require more of the element than do potatoes and legumes while grain crops require only small amounts. Only small applications of borax can be made safely.

The cheapest source of boron is borax. However, boric acid contains 50 per cent more boron than does borax. (See also "Crop Recommendations" and "Methods of Applications.")

Magnesium. Magnesium is another plant food element which is essential for plant growth. Its functions in plants are (1) to produce chlorophyll, (2) to start new growth, (3) to produce oil, (4) to increase and stimulate root development, and (5) to hasten maturity of some crops. A type of chlorosis in plants is sometimes due to a lack of available magnesium.

Symptoms of deficiency consist of the veins becoming light green first, followed soon after by small brown spots appearing in the light green area. These brown spots grow until the entire leaf tissue finally becomes a dark brown, shriveled mass. These symptoms should not be confused with those of potash deficiency. The lack of magnesium delays the maturity of cabbage and causes large yellowish-white areas to form on "puckered" lower leaves which finally die. In the case of potash deficiency, the cabbage leaves first become brown with dry, ragged margins. Corn, tomatoes, and most

other crops growing on magnesium-deficient soils produce leaves having stripes of yellow chlorotic tissue between the veins.

Magnesium can be supplied to plants by dolomitic limestone (10 33 per cent magnesium oxide), kiesenite ("Emjeo" containing 30-31 per cent water-soluble magnesium oxide), and sulphate of potash magnesia (8-10 per cent water-soluble magnesium oxide). (See further discussion under "Crop Recommendations" and "Methods of Application.") Since only a few farmers have reported response from magnesium fertilizer applications, we are not recommending its general use in Idaho.

Manganese. Manganese is another plant food element which is required by plants in very small amounts. Its function in the plant is not very well known, but it is thought to stimulate the growth processes. It is very active in the young, fast-growing tissue. Fast-growing vegetable crops such as spinach and other leafy vegetables show marked response to its application.

The lack of sufficient manganese first causes the vein system of the top leaves of tomatoes and cucumbers to change from green to yellow. The blossom buds turn yellow and fall. Leaves of spinach become golden yellow. Gray specks appear on oat leaves. The greatest deficiency occurs on alkaline or high-lime soils. It is slowly rendered unavailable in the soil.

Manganese sulphate is the most common source of available manganese. (See further discussion under "Methods of Application.")

Soil Amendment.

A soil amendment is some compound which when added to the soil performs a function other than that of supplying plant food. The application of limestone to soils usually performs two functions—namely, neutralizing acidity and supplying calcium for plant growth.

Some of the cut-over, peat and muck soils of northern Idaho are slightly acid. Long Valley, in southern Idaho, contains local areas of acid soils. Very poor to no stands of legumes are obtained on such soils.

Alsike and white clovers grow better on acid soils than does alfalfa. Grain crops and truck crops growing on acid soils also may be improved by lime applications. Since legumes are necessary for improving the fertility of these soils, limestone should be applied wherever field trials have indicated a response.

There are numerous limestone deposits in Idaho which are well distributed over the state. Calcium carbonate, second-grade quick lime, and dolomitic limestone are the forms which have been offered for sale in Idaho. Sixty pounds of pure calcium oxide or quick lime are equivalent to 100 pounds of pure calcium carbonate for neutralizing acidity. It should be ground so that all of it will pass through a 20-mesh screen and 75 per cent will pass through a 100-mesh screen. Since large amounts are used, it should contain

90 per cent calcium carbonate or its equivalent, thereby reducing the amount of carrying or handling charges on nonrequired materials.

Besides correcting the acidity of soils, limestone applications bring about an improved physical condition in acid soils and in black alkali soils. Limed soils are granular, absorb more water and are easier to work and cultivate. Due to the presence of carbon dioxide in the soil moisture, limestone is dissolved fairly rapidly. Where considerable leaching takes place, a large amount of calcium will be found in the drainage water.

Crop Fertilizer Recommendations.

An attempt has been made in the following chart to present in concise manner the responses which can be expected by commercial fertilizer applications to various crops. The author realizes that it is not complete. It is taken for granted that the grower will consult his County Extension Agent or try out the suggested treatments on small plots before treating any large acreage.

Table 3.—General commercial fertilizer recommendations for Idaho[7]

Region	Recommendation	Comments
Northern Idaho		
1. Overflow lands	a. Soluble phosphates on all crops.	This applies to light-colored soils containing appreciable amount of lime.
	b. Small amounts of nitrogen together with soluble phosphates on grains.	Neutral and slightly acid soils should be treated the same as cut-over soils.
	c. Farm manure and green manure.	
2. Cut-over soils.	a. Gypsum for forage legumes.	
	b. Nitrogen for nonlegumes	
	c. Complete fertilizers for nonlegumes.	Where little if any farm manure is applied. Commercial fertilizer applications do not take the place of farm manure.
	d. Boron on legumes where deficiency found.	
	e. Lime on acid soils.	
	f. Farm manure on all crops.	
3. Peat and muck soils.	a. Complete fertilizers for general crops.	Ratio of 1-6-6.
	b. Lime on acid peats.	
	c. Manure on raw peat and muck.	

[7] Following recommendations are based upon results obtained in trials supervised by University of Idaho agencies.

Region	Recommendation	Comments
4. Prairie	a. Gypsum for forage legumes.	
	b. Nitrogen for grains and grasses.	Moisture conditions permitting on areas bordering cut-over soils.
	c. Nitrogen and phosphate (Ratio of 5 lb. nitrogen to 25 lb. available phosphoric acid.)	
Southern Idaho		
1. Northern irrigated mountain valleys.	a. Gypsum for legumes.	Where demonstrations have shown a profitable response from their use.
	b. Soluble phosphates for nonlegumes.	
	c. Large quantities of farm manure applied either alone or together with commercial fertilizers.	
2. Southwestern Idaho.	a. 100 to 200 lbs. soluble phosphate applications on forage legumes.	Where demonstrations have shown a profitable response from their use.
	b. General field and vegetable crops respond to soluble phosphates, nitrogen and phosphates, and complete fertilizers. (Rates varying from 80 to 400 lbs. per acre.)	Depending upon soils, series, and previous treatment of soil, such as rotations and amount of farm manure applied.
	c. Large quantities of farm manure applied either alone or together with commercial fertilizers.	
3. Central and Upper Snake.	a. Most crops respond to soluble phosphate applications alone.	Soils which have received liberal applications of farm manures and green legume manures and on which a forage legume-row crop rotation is followed.
		Some soil series do not respond. See your county agent as to which series do not respond.
	b. Nitrogen plus soluble phosphate for general crops.	
	c. Large quantities of farm manure applied either alone or together with commercial fertilizers.	
	d. Response to complete fertilizers.	Where demonstrations have shown a profitable response from their use on the particular crop.

Region	Recommendation	Comments
4. Southeastern Idaho. (Irrigated) (Drainage toward Great Salt Lake)	a. 100 to 250 lb. applications of soluble phosphate for legumes and general crops.	On high-lime containing soils.
	b. Nitrogen plus phosphate for general crops.	On high-lime soils of average fertility.
	c. Large quantities of farm manures applied either alone or with commercial fertilizers.	
5. Dry land wheat sections.	a. Wheat responds to 35-50 lb. soluble phosphate applications and nitrogen plus phosphate applications.	In years of average or high rainfall only.
	b. 25-50 lb. ammonium sulphate applications to stubble or fallow.	
	c. Green legume manure crops.	Only small amounts. (18 inches to 2 feet high.)

Forage Legumes. Alfalfa, sweet clover, red clover, and other forage legumes have responded to the application of gypsum in northern Idaho and in the mountain valleys lying just south of the Sawtooth range in southern Idaho. The degree of response of alfalfa near Donnelly in Long Valley to gypsum applications is shown in Figure 3.

Figure 3.—Yields of alfalfa in Long Valley are increased by the application of gypsum.

The usual application is 200 pounds of gypsum every other year broadcast in the fall or early spring.

In the irrigated sections of southern Idaho, the application of 100 or 200 pounds of treble superphosphate has brought about the

largest increased yields of alfalfa and the various clovers. Some response has been obtained by the use of potassium sulphate on alfalfa and red clover in local areas of southern Idaho.

Fertilizers can be applied to legumes before seeding, to year-old seedings, or after any cutting has been removed. Preferably, application should be in the early spring or late fall and the land given a light harrowing. Where the soil is very deficient in available phosphate a 100-pound application should be made before seeding the nurse crop and then a further 100-pound application the following spring. When too large applications are made before seeding with a nurse crop, the heavy growth of nurse crop smothers the new seeding. Applied soluble phosphates are rendered unavailable slowly and are not washed out of the soil except in very sandy ones. Large applications can therefore be made without danger of loss. When applying it to old seeding, the field should be lightly harrowed after application, so as to work it into the surface soil and prevent it being carried to the lower end of the field mechanically. The application of fertilizers to forage legume fields will not increase the stand but will increase the number of stems per plant, the plant height, and the size of the leaves.

Red clover and alsike clover seed production has been increased markedly by the application of soluble phosphates in many areas. Maturity is delayed somewhat. Up to the present time few trials have been conducted with the application of phosphate for alfalfa seed production. It is quite possible that the time is not far distant when alfalfa seed production will be so low that the application of phosphate will prove profitable in spite of delayed maturity of the seed crop. New seedings of forage legumes on the cut-over lands have been markedly assisted by small applications of nitrogenous fertilizers. Profitable response has been obtained from the application of farm manure to forage legume land.

Beans. Beans respond to the application of nitrogenous fertilizers. Increase in yield of beans has been obtained by the direct application of phosphates in only a few instances. Some growers have obtained increased yields by phosphate application to the preceding crop while others have obtained decreased yields. Application of 100 to 200 pounds of ammonium sulphate per acre has increased yields on land of average fertility.

Beets. Beets respond profitably to the application of phosphates, under most Idaho conditions. Certain heavy clay soil areas in southwestern Idaho are the main ones upon which we have obtained any response from the application of phosphates. Results in a few instances only have been obtained on the Goose Creek series in the central Snake River valley. Fields which have received only a 10- to 15-load application of farm manures once in the rotation have responded to the application of nitrogen plus phosphate, even though the field be one which was plowed out of alfalfa. This is especially true if the alfalfa has been grazed and no top growth plowed under. No profitable increased yields have been obtained from the application of complete fertilizers or of

potash alone on beet fields. The usual rate of application of phosphate-alone fertilizers is 75 to 200 pounds per acre. The smaller rate can safely be made at the time of planting, by means of proper fertilizer attachments, since there is then little likelihood of plant burning taking place. When heavier applications are made, they should be broadcast previously, or a part of the application broadcast or side-dressed and an application of 50 to 60 pounds only made at time of planting by means of an attachment.

Corn. Corn responds to approximately the same fertilizer treatment as the small grain crops. Phosphates alone have produced the most economical increased yields on soil rich in nitrogenous organic matter. Usually 100 to 200 pounds of phosphate fertilizer are applied per acre. Corn growing on soils low in rapidly decomposing organic matter has responded most profitably to nitrogen plus phosphate and complete fertilizers. The most economical method of application is by means of a fertilizer attachment on the planter. This attachment places the fertilzer in a ribbon on each side of the corn hill and not in contact with the seed.

Fruit Trees. Prunes have responded to the application of nitrogenous fertilizers. General observation and reports of growers indicate that nitrogenous fertilizers might also prove profitable on peach trees. Chlorosis has been reduced considerably by means of ammonium sulphate applications in a few prune and peach orchards, according to some growers. The rate of application has been 1 pound for each 4 to 5 years of age of the tree. It is broadcast in the early spring in a circle under the spread of the tree. Results with the use of phosphates and potash-containing fertilizers in apple and prune experiments have not been profitable. There is little doubt but that in some areas benefit to the tree has been obtained indirectly by growth stimulation of the legume cover crops by phosphate plus potash application.

Grains. Response has been obtained from the application of phosphate alone, phosphate plus nitrogen, and in some instances from the application of nitrogen alone on grains in the cut-over area of northern Idaho. This is especially true on soils which have been producing grain for many years and on which no legume crop has been turned under nor any applications of farm manure made. Grains growing on the peat and muck lands respond very markedly to the application of complete fertilizers. The usual rate of application is 200 pounds of a complete fertilizer (2-20-20).[8]

Grain crops such as wheat, barley, and oats have responded to the application of phosphates alone and nitrogen plus phosphates in northern Idaho prairie lands only under conditions of ample moisture supply. The rates of application are from 30 to 50 pounds of treble superphosphate and 30 to 100 pounds of ammonium sulphate per acre depending upon moisture conditions. It should be applied at planting time, preferably with a drill having a fertilizer attachment. Only phosphate at the above rates can come in contact with the seed without danger of burning. Similar results

[8] See meaning under "Complete Fertilizer" in appendix.

have been obtained in southern Idaho under dry land conditions.

Grain crops respond to farm manure application under all conditions where moisture supply is not a limiting factor. In phosphate-deficient areas, most profitable response is obtained by the application of treble superphosphate together with the manure.

Under irrigated conditions, grains respond to the application of soluble phosphates (100-200 pounds per acre) on soils high in organic matter which are subjected to a rotation consisting of legumes and row crops and which receive applications of farm manure at least once in the rotation. Soils which do not receive heavy applications of farm manures and do not have green legume manure crops turned under on them respond to nitrogen plus phosphate applications and in some instances to the application of complete fertilizers. Fertilizer is usually broadcast before drilling the grain on irrigated farms.

Onions. The results which can be expected from the application of fertilizers to onions are dependent upon the fertility of the soil as influenced by rotation and its previous fertilizer treatment. Soils which have received only an application of 15 loads of farm manure during the preceding one or two years can be expected to respond markedly to the application of nitrogen plus phosphate fertilizers or complete fertilizers, while soils which have received heavy applications of farm manures will respond most profitably to the application of phosphate alone if the crop is to be stored. This is especially true in case of seed production, since one of phosphate's important functions is the production of fruit. The rate of application varies from 200 pounds soluble phosphate fertilizer to 500 and 600 pounds of some complete fertilizer high in phosphate and potash. Frequently half of the total application is made at time of planting, and the remainder is applied in two applications by means of a fertilizer attachment on the cultivator during the early part of the growing season. The late application of nitrogen to onions as a side-dressing has been especially profitable.

Pastures. The carrying capacity of Idaho pastures can be increased considerably by the seeding of better pasture mixtures, practice of pasture management, and judicious use of commercial fertilizers.

The most economical milk production is possible when cows receive most of their feed from pastures. The grazing season can be lengthened and the carrying capacity increased by the application of farm manures and commercial fertilizers.

The growth of the legume fraction in the pasture mixture is especially increased by the application of soluble phosphates in southern Idaho and gypsum in northern Idaho. Grasses are also benefitted by phosphate applications when growing on low soluble phosphate-containing soils. The weed population is reduced in old pastures by the application of commercial fertilizers.

Fertilizers such as ammonium sulphate, treble superphosphate, and gypsum should be broadcast in late fall, winter, or very early

spring—preferably during the winter. They can be applied at the rate of 100 to 200 pounds per acre. If applied to new seeding, they should be applied previous to final seedbed preparations. They should be applied previous to any cultivation or rejuvenation of old pastures. Nitrogen-containing fertilizers are carried to greater soil depths very easily while phosphates will be carried only 1 or 2 inches deeper during 3 to 4 years. On very sandy soils, both elements are leached out of the soil fairly rapidly. Where farm manures are to be applied to the pasture, the commercial fertilizers can be applied with the manure.

When straw mulching is practiced, 150 pounds of ammonium sulphate should be applied during the late winter of the second year. Straw contains very little nitrogen. Bacteria decomposing the straw will rob the grasses of soil nitrogen, if the amount present is insufficient for both plant and bacteria, in order to carry on their life processes. Straw mulching in the fall increases the carrying capacity of pasture markedly.

Peas. In northern Idaho, no yield increases have been obtained from the application of commercial fertilizers to peas. In southern irrigated districts, peas have responded to the application of phosphates on soils of high fertility. Fine results are obtained from the application of nitrogen plus phosphates on soils which do not receive liberal applications of farm manure from time to time.

Potatoes. Potatoes growing in peat and muck soils respond to the application of 200-400 pounds of complete fertilizer having a ratio of 2-20-20. On other soils in northern Idaho, commercial fertilizers should not be applied until the organic matter supply has been restored. Then they respond to the application of 150-400 pounds of phosphate plus nitrogen and in some instances to the application of a complete fertilizer. Indirect response has been obtained from the application of gypsum to the previous alfalfa crop.

Potatoes growing in the irrigated sections of southern Idaho respond to the application of commercial fertilizers, depending upon the fertility of the soil, which is influenced by its past management. In order to obtain maximum profit from the use of commercial fertilizers, heavy applications of organic matter should be applied by turning under green legume growth, which has received an application of soluble phosphates, or by the application of farm manures to which soluble phosphate has been added. Potatoes growing on soils low in rapidly decomposing organic matter or fields not receiving large quantities of farm manure or green manure crops respond very profitably to the application of nitrogen plus phosphate. Potatoes growing on soils which are very low in organic matter will respond most profitably to the application of nitrogen alone. The direct application of commercial fertilizers to potatoes usually has not proved profitable where an abundance of nutrients are present due to heavy applications of farm manure

and the turning under of large legume green manure crops which have received previous fertilizer treatment.

The rate of fertilizer application varies from 150 to 400 pounds, depending upon the plant food content of the material. Applications by means of a fertilizer attachment on the potato planter have been found the most economical on many Idaho farms. By means of the attachment the fertilizer is placed 2 inches to each side and 1 inch below the level of the seed piece. Sidedressing with nitrogen at time of last cultivation has been especially profitable in low humus-containing soils.

Truck Crops. Response from fertilizers on truck crops is dependent upon the type of crop grown and soil conditions. Heavy applications of farm manures should be considered as pre-treatment for the production of truck crops. Root and fruit truck crops have responded to phosphates alone and to complete fertilizers high in potash. Leafy vegetables growing in soils high in nitrogen and containing an average amount of available phosphates have responded to phosphate plus potash applications (ratio 1-1). Celery and lettuce in particular have responded markedly to potash alone applications. Growers have reported that fall spinach suffering from chlorosis has been benefitted by manganese sulphate applications. (See also "Methods of Application.")

Methods of Application of Commercial Fertilizers.

Fertilizers can be applied in various ways. Cost of the application, desired response, and type of crop are factors to be considered in choosing a method of application. The lowest cost of application is possible when fertilizers are applied in the same operation with planting or cultivation. Where considerable residual effect is desired, it should be broadcast. If applied in the row to one crop, the growth and maturity of the following crop will be quite variable. The fertilizer should be broadcast on established forage crops and the soil stirred slightly by light harrowing or by the use of brush drags. The maximum immediate response from its use on row crops other than beets is obtained when applied in bands 1 to 2 inches to the side and 1 to 2 inches below the seed level. Fine response has been obtained when applied 1 inch to the side of the beet seed.

It is more profitable to make small applications of fertilizer each year when they are to be applied locally or in close proximity to the seed.

Frequently it is advantageous to make only part of the total fertilizer application at planting time, and then make one or two smaller applications during the growing season. In the case of truck crops and leafy vegetables this is common practice.

Fine response from sidedressing has been obtained on row crops. Application can be made by means of attachments on cultivators or separate distributing equipment. The fertilizer should not be distributed any closer than 2 inches to very small plants or seeds. When applied at later stages of growth, it should be

distributed in the root zone, 3 to 5 inches from the stem of the plant so as to destroy only a small percentage of the roots.

Gypsum and Calcium Cyanamid. Some fertilizers such as gypsum and calcium cyanamid should be applied in the fall or 2 to 3 weeks previous to planting. Calcium cyanamid can be used in composting strawy manure. Fifty pounds of it should be mixed with each ton of straw.

Potash. Since there is very little loss of available potash by leaching and fixation into unavailable forms in deficient areas, applications need be made only when the plants have removed most of the previous treatment. Depending upon type of crop grown, relatively large applications of potash can be made. It should be applied together with phosphate or in the form of a complete fertilizer.

Manure. Pea, bean, and forage legume land, which will be planted to beets and early potatoes the following year, should receive an application of manure in the fall previous to disking, crowning, or plowing. Earlier spring grazing is possible where manure is applied to the pastures in the fall.

Phosphates. Soluble phosphate fertilizers can be applied in many ways and at nearly all seasons of the year. Applications can be made to the nurse crop, to alfalfa fields in the spring, or to the young stand after the first cutting has been hauled off the field, or in the fall. Best results are obtained from its use on beets when 75 to 100 pounds are applied at planting time. Applications to potatoes can be made by means of side placement equipment at planting time or at the time of first cultivation. Applications to vegetable crops are either made at the time of planting or as a sidedressing at time of first cultivation.

Due to the fact that many of our irrigated soils are very deficient in available phosphorus and the manure is relatively low in available phosphrous, the application of phosphorus together with farm manures has proved very profitable at all seasons.

Boron. The rate of application of boron varies from 10 to 40 pounds of borax per acre. Excessive rates of application are toxic. This material can be applied broadcast, mixed with farm manures or other commercial fertilizers. Boron fertilizers should first be applied on only a small plot of land to determine its value before applying it on the entire field. Fall applications are preferable.

Magnesium. Where magnesium fertilizers have shown response, the rate of application varies with the crop. When magnesium-containing fertilizers are applied to potatoes growing on sandy soils, only 10 to 15 pounds of available magnesium are applied. Twenty-five pounds of available magnesium oxide should be applied on magnesium-deficient soils planted to cabbage. Magnesium also can be supplied by the application of large quantities of farm manure which contains about 10 pounds of readily available magnesium oxide per ton.

Iron. Iron can be applied in various ways. When quick response is desired, or when treating shrubs and flowers, a 1 per cent solution of iron sulphate (copperas) should be sprayed over the foliage sufficiently often to maintain a green color during the growing season. Chlorotic trees (at least four inches in diameter) can be treated by drilling some ½-inch holes at the base of the trunk, placing some iron citrate, iron tartrate, or ferric ammonium citrate in the hole, and then sealing it with sealing wax. The treatment usually will last for four to five years.

Manganese. Manganese is usually applied in the form of manganese sulphate. The rate per acre varies with the crop. If applied broadcast, 40 to 75 pounds per acre is sufficient. It also can be sprayed on the young growing plants. If chlorosis has already started, spraying usually will stop its spread. It is applied on garden crops by spraying during the first three to four weeks of growth. When it is applied as a spray, 100 pounds are dissolved in 500 gallons of water. It also can be mixed safely with other fertilizers before application. It is slowly rendered unavailable.

Limestone. Limestone is usually disked or harrowed into soils known to be acid before seeding legumes or any other crop. It also may be applied in the fall of the year to any crop, but preferably it should be applied to the legume fields where its value will show strikingly. Application should be made on a dry clear day when there is no dew on the plants. It also can be applied together with farm manures. It should be disked into the soil rather than plowed under. It also can be applied by means of a limestone or an end-gate spreader. The rate of application varies from one to three or more tons, depending upon the individual soil requirement. Soils in the lower Payette, Boise, Snake, and Bear River drainage areas contain sufficient lime for crop production.

Home Mixing of Fertilizers.

There is usually a deficiency of more than one plant food in many field soils. Where this is the case, it becomes necessary to add more than one plant food element at a time. Fertilizers containing two plant food elements are called semicomplete fertilizers and those containing nitrogen, phosphorus, and potash are called complete fertilizers.

It frequently is desirable to apply commercial fertilizers containing two or more elements such as nitrogen and phosphorus, or nitrogen, phosphorus and potassium, or any other combination. These mixtures usually are prepared by mixing two or more materials containing single elements. However, nitrogen and phosphorus can be obtained as ammonium phosphate; potash and nitrogen as potassium nitrate; and phosphate and potash as potassium phosphate.

Mixed and complete fertilizers vary widely in the percentage of nitrogen, phosphorus, and potash which they contain. Mixed or unmixed fertilizer materials containing high total percentages of these constituents are known as high grade or high analysis while

those containing low percentages are known as low grade or low analysis. Between these two terms, there are all possible degrees of gradation.[9]

Mixed fertilizers should always be purchased on the basis of unit content cost and not on a price basis alone. Low analysis fertilizers usually contain high percentages of fillers.[10]

A part of the cost of the fertilizers is consumed by freight and handling of filler material which does not contribute to the fertilizer value. Therefore, only high-analysis products should be purchased. By increasing the total plant food content, the cost per pound of plant food is frequently reduced 1 to 3 cents per pound.

Where large quantities of mixed fertilizer are used, a considerable saving in cost frequently can be obtained by home mixing. When the spread between the retail cost of ingredients and retail price of mixed goods per ton is only $5, it may not be worth while to practice home mixing.

There is nothing difficult about mixing fertilizers. A little care in selection of materials and performing the mixing in a workmanlike manner are the main factors to be considered. Some of the terms used by the fertilizer mixing trade are:

(1) *Fertilizer formula*: The term formula should be interpreted as expressing the quantity and grade of the crude stock materials used in making a fertilizer mixture. For example, 800 pounds of 16 per cent superphosphate, 800 pounds of 9 per cent tankage, and 400 pounds of sulphate of potash constitute an open fertilizer formula.

(2) *Analysis*: The word analysis, as applied to fertilizers shall designate the percentage composition of the product expressed in terms of nitrogen, phosphoric acid, and potash in their various forms. For example, 5-15-5 means that the mixture contains 5 per cent total nitrogen (N), 15 per cent available phosphoric acid (P_2O_5), and 5 per cent available potash (K_2O).

(3) *Unit*: The unit of plant food is 20 pounds or 1 per cent of a ton. For example, ammonium sulphate contains 20 per cent nitrogen which is equivalent to 20 units of nitrogen per ton (400 pounds).

The Idaho fertilizer law provides that all bags of fertilizer offered for sale must be labeled stating the percentage of each ingredient present therein. (See Appendix.)

Certain materials cannot be mixed without producing a product which will cake and therefore will not drill satisfactorily. Loss of ammonia or reversion of soluble phosphate to the insoluble form may take place.

Table 2 contains the most common fertilizer materials offered for sale in Idaho. The mixing can be done during slack seasons. Lists of firms selling fertilizers can be obtained from your County Extension Agent.

[9] See Appendix for definition.
[10] See Appendix for definition.

Table 4.—Fertilizers and soil amendments which may or may not be safely mixed.[11]

Calcium hydroxide (slaked lime) Calcium cyanamid	Should not be mixed with	Ammonium sulphate, nitrate, chloride, or phosphate Animal materials (bone, tankage, blood, fish scrap, farm manure, etc.)
Calcium hydroxide Calcium carbonate Basic calcium nitrate Calcium cyanamid	Should not be mixed with	Soluble phosphates
Calcium hydroxide (slaked lime) Basic calcium nitrate	Should not be mixed with except just before application to soil	Sodium nitrate Calcium nitrate Potassium salts Potash manure salts Urea

[11] If some fertilizer not discussed in this bulletin is used, information regarding its use can be obtained by writing to the Extension Soils Specialist, University of Idaho, Moscow, Idaho.

The necessary mixing equipment is simple—a small platform scale, shovels or hoes, and any tight barn floor or wagon box. The mixture should be passed through a ¼-inch mesh screen and spread in layers, the bulkiest first, followed by the next bulky and so on until the least bulky is spread over the pile. It should then be thoroughly mixed by shoveling or hoeing as in mixing mortar. This will require turning four times. Two men with shovels should screen, mix, and bag a ton of fertilizer in one-half to three-quarters of an hour. The rotary mixer used for concrete mixing also can be used for mixing fertilizer. The mixing should continue until the materials are uniformly mixed and no streaks of color are apparent. The material should then be sacked and stored in a dry place until used.

In calculating the number of pounds of each material required, it is not necessary to calculate the exact percentage or pounds required. A sample calculation is given herewith. A ton of 5-15-10 mixed fertilizer is to be prepared, in which ammonium sulphate (21 per cent nitrogen), treble superphosphate (43 per cent P_2O_5) and potassium sulphate (50 per cent K_2O) will be the sources of nitrogen, phosphoric acid, and potash respectively. The amount of ammonium sulphate required for 1 ton of the mixture will be

$$\frac{5 \text{ (percentage of nitrogen desired in mixture)}}{21 \text{ (percentage of nitrogen present in ammonium sulphate}} \text{X}$$

2000 pounds (ton) = 476 pounds of ammonium sulphate.

The amount of treble superphosphate required to make one ton of the mixture will be

$$\frac{15 \text{ (percentage of } P_2O_5 \text{ desired)}}{43 \text{ (percentage of } P_2O_5 \text{ present in treble superphosphate)}} \text{X}$$

2,000 = 700 pounds in round numbers of treble superphosphate.

Likewise the amount of potassium sulphate required will be 10/50 × 2,000 pounds = 400 pounds. The total weight of plant nutrient carriers will be 476 + 700 + 400 = 1,576 pounds. It will then be necessary to mix 424 pounds of some filler with the above ingredients in order to prepare a ton of 5-15-10 fertilizer.

It usually happens that the sum of the amounts of the various ingredients is less than 2,000 pounds. It then becomes necessary to apply either a proportionately smaller amount of the fertilizer or to include a filler. A filler is usually some inert material having no fertilizer value. This material may function as a drier or an absorbent of moisture, thereby preventing caking of the mixture. Finely ground fillers often improve the drilling qualities of the fertilizer. Frequently the filler is some additional fertilizer element. Fine dry muck and peat are excellent driers but are very bulky. Some other driers frequently used are finely ground rock phosphate, fine sand, gypsum (gypsum should not be used in southern Idaho), fine granular dry earth, and ground sheep manure. If the grower does not desire to use filler, he can use a proportionately smaller amount of the mixture. For example, if the total weight of the plant food carrier ingredients is 1,500 pounds in place of 2,000 pounds, then only 75 per cent of the usual rate of application will be necessary.

Table 5.—Quantities of fertilizer ingredients to be used to give definite percentages in a ton of mixture[12]

Ingredient	1 per cent lb.	2 per cent lb.	3 per cent lb.	4 per cent lb.	5 per cent lb.	6 per cent lb.	7 per cent lb.	8 per cent lb.	9 per cent lb.	10 per cent lb.
Carriers of Nitrogen (N)										
Sodium Nitrate (16% N)	125	250	375	500	625	750	875	1000	1125	1250
Sulphate of Ammonia (21% N)	95	190	286	381	476	571	666	762	857	952
Fish scrap (8% N)	250	500	750	1000	1250	1500	1750	2000	.....	.....
Carriers of Phosphoric Acid (P_2O_5)										
Super-phos. (20% P_2O_5)	100	200	300	400	500	600	700	800	900	1000
Triple super-phos. 45% P_2O_5)	44	89	133	178	222	266	311	356	400	443
Carriers of Potash (K_2O)										
Potassium chloride (50% K_2O)	40	80	120	160	200	240	280	320	360	400
Potassium chloride (60% K_2O)	33	67	100	133	166	200	233	266	300	333
Potassium sulphate (50% K_2O)	40	80	120	160	200	240	280	320	360	400

[12] When the combined materials do not total 2,000 pounds, a filler may be used to bring up the weight.

When mixtures are made a considerable time before application, or if the season is damp, a drying filler should by all means be included. The mixed materials should be stored in as dry a place as possible until time for application.

The calculated amount of each fertilizer required in preparing a ton of various fertilizer formulas is shown in Table 6. To make a ton of the various mixtures shown in column 1, use the amounts shown in columns 2, 3, 4, and 5, or combinations of them. The required amount of filler is shown in column 8. If other ingredients are to be used, then the amounts can be calculated in accordance with methods shown in Table 5, and discussed above.

Table 6.—Fertilizer mixtures and amounts of ingredients required in their preparation

Analysis of fertilizer mixture	Sodium Nitrate 16% N lb.	Ammon. Sulphate 21% N lb.	Super-phosphate 45% P_2O_5 lb.	Super-phosphate 43% P_2O_5 lb.	Potassium Sulphate 50% K_2O lb.	Total Fertilizer Material lb.	Filler to make 2,000 lb.
2-20-20	250	.....	.....	930	800	1980	20
3-20-20	.....	285	888	.....	800	1995	5
4-12- 4	.....	381	533	.....	160	1074	926
4-18-20	.....	400	800	.....	800	2000	.....
4-20- 6	.....	381	.....	930	240	1551	449
5-15- 5	.....	476	.....	698	200	1374	626
5-20-12	.....	476	.....	930	480	1886	114
6-16-17	.....	583	.....	737	680	2000	.....
6-30- 0	.....	583	.....	1417	.....	2000	.....
8-10- 8	.....	762	444	.....	320	1526	474
14-15-0	.....	1333	666	.....	.....	2000	.....

Fertilizers should be purchased on the unit of plant food cost basis and not on the basis of price of mixed goods since low-priced goods usually contain high-priced units of plant food.

Further information concerning home mixing of fertilizer can be obtained by sending for Leaflet No. 70, Office of Information, United States Department of Agriculture, from which some of the preceding material was taken.

Residual Effect.

The amount of benefit which can be expected by the crop following the one receiving the fertilizer application is influenced by the size of the application, kind of fertilizer applied, type of crop, and the kind of soil to which the application was made. Table 7 presents some data obtained in Cassia county during the past several years. The residual response is quite large in the fourth year after application. If the application was equal only to the amount contained in the first crop, little residual effect could be expected.

In spite of the fact that there is an insufficient amount of some element, such as phosphate, available in the soil at any one time to produce maximum yield, there is frequently sufficient of it becoming available which, together with the amount applied, will

cause increased yields to be obtained for a considerable period long after the crops have utilized the amount present in the original application. Field demonstrations are useful in determining the required frequency of applications necessary for obtaining maximum yields.

Phosphate and potash-containing fertilizers are not leached out of soils very rapidly. It is only in the drainage water from sandy soils that appreciable amounts of these two plant nutrients are found. Phosphates and potash fertilizers move downward in the soil very slowly. Under most Idaho conditions, sufficiently large applications of phosphate- and potash-containing fertilizers can be profitably made at one time to last for several years. Most nitrogen fertilizers recommended for Idaho are water-soluble and are, therefore, easily leached out of the soil. Applications of nitrogen fertilizers should not be larger than what will be required by that year's crop.

Table 7.—Influence of rate of application on the residual effect of phosphate single applications made to alfalfa in 1934[13]

Year	Cutting	Increase in yield over untreated areas due to the application of	
		125 lb. Treble superphosphate	250 lb. Treble superphosphate
1934	2nd	7 per cent	30 per cent
1935	2nd	20 per cent	125 per cent
1936	1st	19 per cent	81 per cent
	2nd	38 per cent	30 per cent
1937	1st	50 per cent	87 per cent

[13] Results obtained in cooperative demonstration in Cassia county.

Appendix

A. Definitions of terms used in the fertilizer industry.

1. *Available or soluble phosphoric acid*—The sum of the water-soluble and the citrate-soluble phosphoric acid.
2. *Commercial fertilizer*—Any form of plant food not obtained from animal manures or plant residues. They may be pure chemicals or byproducts of some industry. They contain definite amounts of plant food.
3. *Complete fertilizers*—Fertilizer mixtures containing nitrogen, phosphorus, and potash. They may be present in various ratios which may be or may not be suitable for the specific crop. For example, 3-16-10.
4. *Concentrated* (or multiple strength)—See "Low Grade."
5. *Filler*—Any material which is added to a mixture of straight fertilizers for the purpose of improving the mechanical condition of the mixture, acting as a drier or adding bulk to the mixture. Sheep manure is probably the best filler for use in Idaho, since it contains some plant food as well as organic matter. Fine sand, gypsum, and muck are other materials which can be used.
6. *High grade*—See "Low Grade."
7. *Insoluble*—Not soluble. As applied to phosphoric acid in fertilizers it means that portion of the total phosphoric acid which is soluble in neither water nor ammonium citrate. It is a plant food or plant food constituent which is in such form or combination that plants cannot utilize it, or it may become available so slowly under favorable conditions that it does not furnish appreciable amounts of plant food utilizable by growing crops.
8. *Low-analysis or low-grade fertilizer*—Can be considered only as a general term. As an approximate generalization, complete mixed fertilizers containing a total plant food content of less than 15 per cent nitrogen, available phosphoric acid, and water-soluble potash are regarded as low analysis or low grade. Medium-grade fertilizers are those containing 16-20 per cent total; high grade are those containing 20-30 per cent total; concentrated- or multiple-strength fertilizers are those containing over 30 per cent total plant food.
9. *Medium grade*—See "Low Grade."
10. *Mixed goods*—Materials containing more than one element.
11. *pH*—A symbol for expressing the relative acidity or alkalinity of the soil. All values less than 7.0 mean that the material is acid in reaction. All values greater than 7.0 mean that the material is alkaline in reaction.
12. *Phosphoric acid* (P_2O_5)—Phosphorus present expressed as its oxide in the fertilizer.

13. *Plant food*—A substance which supplies any constituent necessary for the nourishment of plants.
14. *Potash* (K_2O)—Potassium present expressed as its oxide in the fertilizer.
15. *Straight goods*—Materials containing only one plant food element.

B. Some of the provisions of the Idaho fertilizer law follow:

This law governs the sale of all products sold for fertilizing, manurial, soil enriching, or soil corrective purposes with the exception of animal manures which have not been artificially treated. The fertilizer containers must have printed on them a statement of the contents or have a tag attached which includes the following information:

a. The net weight of the contents of the package.
b. The name, brand, or trademark.
c. Name and principal address of the manufacturer or person responsible for placing the commodity on the market.
d. The minimum percentage and source of nitrogen in available form.
e. The minimum percentage and source of potash (K_2O) soluble in distilled water.
f. The minimum percentage and source of available phosphoric acid (P_2O_5), and also the total phosphoric acid content.
9. The content of any other material from which a benefit is claimed shall be stated.

All containers of unmixed products such as nitrate of soda, sulphate of ammonia, sulphate and muriate of potash, lime, gypsum, aluminite, and phosphate, or other fertilizer or soil correcting substances shall have stamped thereon, a plain statement in the English language of the name of said material and the guaranteed per cent of the elements or element contained which give the commodity its value as a fertilizer.

The law provides for analysis of samples of the various fertilizer products at least once a year for the purpose of determining whether or not they conform to the law. The results of these analyses are published each year in the report of the Commissioner of Agriculture.

Copies of the complete fertilizer law may be obtained by writing to the State Commissioner of Agriculture, Boise, Idaho.